DATA PLAYBACK EQUIPMENT

BACKGROUND OF THE INVENTION

The present invention relates to data playback equipment for playing back data

5 recorded on a disk medium, such as an optical disk drive and a hard disk drive.

The error rate of played-back data is conventionally used as a yardstick for the

quality of a signal played back by data playback equipment, and reducing the error rate is

important. However, under use of the error correction technology such as error correcting

code (ECC), system breakdown will occur if the error limit is exceeded even slightly,

10 while no error arises at all within the error limit.

In data playback equipment, it is very difficult to execute learning for system

optimization using the error rate of played-back data as a parameter. Conventionally,

therefore, to optimize the margin of the error rate, the jitter amount is detected from an

analog signal obtained from a disk medium, and learning is executed using the jitter

15 amount (see Japanese Laid-Open Patent Publication No. 8-45081, No. 2000-173060 and

No. 2001-23167).

The jitter amount is a very useful parameter for determining the margin of the error

rate. However, with introduction of technologies such as partial response maximum

likelihood (PRML) and adaptive equalization thanks to the recent advance of the digital

20 technology, the jitter amount is no more a parameter always correlated with the error rate.

In this situation, a new parameter replacing the jitter amount used in the conventional

analog-related techniques is required.

SUMMARY OF THE INVENTION

25 An object of the present invention is providing a parameter useful for securing the

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margin of the err r rate of played-back data, replacing the conventi nal jitter amount used for information playback equipment.

To attain the above object, according to the present invention, an analog signal obtained from a disk medium is converted to a digital value, and the error between the

5 digital value and its ideal value is used as a new parameter.

Specifically, the present invention is directed to data playback equipment for playing back data recorded on a disk medium, including: analog-to-digital conversion means for converting an analog signal obtained from the disk medium to a digital value; target holding means for holding an ideal value for a signal related to an output of the

10 analog-to-digital conversion means as a target; and error detection means for detecting an error between the signal related to the output of the analog-to-digital conversion means and an output of the target holding means and generating a signal representing the error as a parameter signal correlated with an error rate of played-back data, wherein the quality of the analog signal is adjusted so that the parameter signal is minimized, to thereby optimize

15 the margin of the error rate of played-back data.

The data playback equipment may further includes: a filter receiving the output of the analog-to-digital conversion means, the filter having taps of which coefficients are variable; and error minimization means for updating the tap coefficients of the filter so that an error between an output of the filter and the output of the target holding means is

20 minimized. By having these means, the tap coefficients of the filter are first optimized, and then the quality of the analog signal can be adjusted so that the parameter signal is minimized.

The filter may be a partial response (PR) equalization filter for realizing PR equalization. The target holding means may hold a plurality of ideal values for the PR

25 equalization as targets. The error detection means and the error minimization means may

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respectively compare a plurality of tap outputs of the filter reflecting the output of the analog-to-digital conversion means with the plurality of ideal values.

BRIEF DESCRIPTION OF THE DRAWINGS

5　　　　FIG. 1 is a block diagram showing a configuration of information playback equipment of the present invention.

FIG. 2 is a view showing a waveform of an analog signal input into an ADC in FIG. 1 and its ideal sample points.

FIG. 3 is a view demonstrating that sample points represented by an output digital

10　signal of the ADC in FIG. 1 are actually deviated from equalization targets.

FIG. 4 is a view demonstrating that an output signal of a FIR filter in FIG. 1 has been corrected by an LMS block.

FIG. 5 is a view showing waveforms of error signals output from an error detection circuit in FIG. 1.

15　　　　FIG. 6 is a view showing a waveform of a parameter signal output from an addition/weighting circuit in FIG. 1.

FIG. 7 is a view demonstrating pass/fail decision on the quality of a disk medium by the information playback equipment of FIG. 1.

20　　　　## DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. 1 shows a configuration of an optical disk drive 20 as the data playback equipment of the present invention. The optical disk drive 20 of FIG. 1, which is data playback equipment for playing back data recorded on an optical disk 5 as a disk medium, includes a pickup 8, a pickup driver 9, an equalizer (EQ) 10, an analog-to-digital converter

25　(ADC) 11, a target holding circuit 12, an error detection circuit 13, a phase-locked loop

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(PLL) circuit **14**, an error minimization circuit **15**, a PR equalization filter **16**, an addition/weighting circuit **17** and an arithmetic circuit **18**. In the illustrated example, a 3-tap finite impulse response (FIR) filter is used as the PR equalization filter **16**, and a least mean square (LMS) block according the method of least squares is used as the error

5　minimization circuit **15**.

The pickup **8** is a means for irradiating the optical disk **5** with a laser beam. The pickup driver **9** sends a control signal **S90** to the pickup **8** to control focusing and tracking of the laser beam. The equalizer **10** receives an output signal **S80** of the pickup **8** and outputs an analog signal **S100**. The ADC **11** converts the analog signal **S100** to a digital

10　signal **S110**, which is given to the PLL circuit **14** and the FIR filter **16**. The PLL circuit **14** extracts a clock from the digital signal **S110** and supplies the extracted clock to the ADC **11** as the sampling clock. The FIR filter **16**, receiving the digital signal **S110**, has three taps of which coefficients are variable. The output of the FIR filter **16** is used as the played-back data.

15　The target holding circuit **12** holds a plurality of ideal values for PR equalization as targets. Assume herein that the target holding circuit **12** holds three equalization targets (ET1, ET2 and ET3) prepared for three tap outputs of the FIR filter **16**. The LMS block **15** compares three tap outputs **S161** of the FIR filter **16** reflecting the sequentially changing output of the ADC **11** with the respective equalization targets (ET1, ET2 and

20　ET3), and supplies a signal **S150** to the FIR filter **16** for updating the tap coefficients of the FIR filter **16** so that the square errors between the tap outputs and the targets are minimized. The error detection circuit **13** compares three tap outputs **S160** of the FIR filter **16** reflecting the sequentially changing output of the ADC **11** with the equalization targets (ET1, ET2 and ET3) represented by signals **S120**, detects the errors between the tap

25　outputs and the targets with three subtract rs, and outputs signals representing the detected

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errors as error signals **S130** related with the error rate of played-back data. The addition/weighting circuit **17**, composed of three multipliers and one adder, performs arbitrary weighting and addition for the outputs **S130** of the error detection circuit **13**, to thereby obtain a parameter signal **S170**. The arithmetic circuit **18** supplies a quality

5   adjustment signal **S180** obtained based on the parameter signal **S170** to the pickup driver **9** and the equalizer **10**. That is, the arithmetic circuit **18** has a function of optimizing the margin of the error rate of the played-back data by adjusting the quality of the analog signal **S100** so that the parameter signal **S170** is minimized. The output signals **S160** and **S161** of the FIR filter **16** may be the same signals.

10   The operation of the optical disk drive **20** of FIG. 1 will be described with reference to FIGS. 2 to 6. FIG. 2 shows the waveform of the analog signal **S100** input into the ADC **11** and its ideal sample points. In FIG. 2, each sample point corresponds with one of the equalization targets (**ET1**, **ET2** and **ET3**). Actually, however, as shown in FIG. 3, sample points represented by the digital signal **S110** output from the ADC **11** are deviated from the

15   equalization targets (**ET1**, **ET2** and **ET3**). In view of this fact, the LMS block **15** updates the tap coefficients of the FIR filter **16** so that the square errors between the three tap outputs **S161** of the FIR filter **16** and the equalization targets (**ET1**, **ET2** and **ET3**) are minimized. FIG. 4 shows successful correction of the three tap outputs **S160** of the FIR filter **16** by the LMS block **15**. In response to the corrected three tap outputs **S160**, the

20   error detection circuit **13** outputs the error signals **S130** as shown in FIG. 5. The addition/weighting circuit **17** generates the parameter signal **S170** based on the received error signals **S130**. FIG. 6 shows the waveform of the parameter signal **S170** obtained when all the multiplication factors are 1. The arithmetic circuit **18** controls the pickup driver **9** and the equalizer **10** so that the parameter signal **S170** is minimized, to thereby

25   optimize the margin of the error rate of the played-back data.

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Thus, with the ptical disk drive **20** having the configurati n shown in FIG. **1**, it is possible to execute learning for the focusing and tracking control of the pickup **8** and the characteristic adjustment of the equalizer **10**, to optimize the margin of the error rate. This learning may be executed for an arbitrary sector or an arbitrary track of the optical disk **5**.

5   The parameter signal **S170** may be accumulated at a frequency proportional to the clock frequency of the PLL circuit **14**, or a signal obtained by adding the parameter signal **S170** and a jitter signal at a predetermined ratio may be accumulated, to permit stable learning irrespective of a variation in rotation of the optical disk **5**.

As a simpler configuration, the digital signal **S110** may be directly sent to the error

10   detection circuit **13** omitting the placement of the PR equalization filter **16** and the error minimization circuit **15** in FIG. **1**. Alternatively, a low pass filter (LPF) that is not meant for waveform equalization may be adopted in place of the PR equalization filter **16**. The error detection circuit **13** may compute the accumulated values of the differences between the filter output signals **S160** and the targets **S120**.

15   In the case of use of the PR equalization filter **16** as in FIG. **1**, all the error signals **S130** output from the error detection circuit **13** may be used as parameters correlated with the error rate, or only one output (for example, the median value) may be selected by the addition/weighting circuit **17**. Otherwise, the sum of arbitrary two outputs or the sum of at least three or all the outputs may be used by the addition/weighting circuit **17** as a

20   parameter.

The arithmetic circuit **18** may use the parameter signal **S170** as information indicating the quality of the optical disk **5**. This will be described with reference to FIG. **7**.

FIG. **7** shows the correlation between the quality adjustment signal **S180** and the parameter signal **S170** obtained during adjustment of the quality of the analog signal **S100**

25   for each of three disks **A**, **B** and **C**. The disks **A**, **B** and **C** can provide the highest quality

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of played-back data when the quality of the analog signal is adjusted with the minimum values X, Y and Z, respectively. As for the disk A, in which the minimum value X is greater than a criterion R, it is decided that the medium is defective. As for the disk B, in which the minimum value Y is smaller than the criterion R, it is decided that the medium

5　is not defective but the optical disk drive 20 suffers a breakdown in an event that playback of data on the disk B by the optical disk drive 20 fails. The same quality pass/fail decision as that for the disk B is made for the disk C.

As described above, in an event that playback of data by the optical disk drive 20 fails, which is responsible for this failure, the optical disk 5 or the optical disk drive 20, can

10　be easily determined by using the parameter signal S170, without the necessity of complicate signal analysis. This improves debugging performance.

The functions of the arithmetic circuit 18 may be implemented by a personal computer or the like externally connected to the optical disk drive 20.

As described above, the data playback equipment of the present invention can

15　provide a useful parameter replacing the conventional jitter amount, and is valuable in the fields of optical disk drives, hard disk drives and the like.

While the present invention has been described in a preferred embodiment, it will be apparent to those skilled in the art that the disclosed invention may be modified in numerous ways and may assume many embodiments other than that specifically set out

20　and described above. Accordingly, it is intended by the appended claims to cover all modifications of the invention which fall within the true spirit and scope of the invention.